The Use of the Thermal Response Number to Characterize Land Surface Energy Flux

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On a global scale, initial research by climate modelers identified the importance of including the linkages between different kinds of land surfaces and the atmosphere as factors influencing global patterns of rainfall, temperature, and atmospheric circulation.[5] Yet, these linkages have not been fully characterized in global models of atmospheric processes and climate change.[1] General circulation models (GCM's) suffer from a lack of detail about how different surfaces respond thermally, and hence, affect local climatic processes. Hewitson[2] states "GCM's are currently unable to reliably predict the regional climate change resulting from global warming, and it is at the regional scale that predictions are required for understanding human and environmental responses." These models could be improved by using thermal infrared measurements to quantify the biophysical response of the surface in relation to environmental energy fluxes (radiative, latent, conductive, and convective). Information at larger spatial resolution is also needed by the global modelers for improving their predictive capabilities, since the heterogeneity in surface types makes it difficult to characterize averages over the smaller spatial resolution used in global climate models.

The purpose of this study is to characterize the landscape in terms of a functional classification using the thermal response numbers (TRN) for the incorporation into the PSU/NCAR Penn State University/ National Center for Atmospheric Research MM5 model for mesoscale water vapor transport and convective activity.

One approach to characterizing the landscape is to take the U.S. Geological Survey landcover data and incorporate it into the Regional Atmospheric Modeling System (RAMS.)[4] This approach uses a structural classification based on landcover type instead of a functional classification to assess the impact of landcover in the RAMS output. The major problem with this approach is that the partitioning of the surface energy fluxes is spatially variable within and between each landcover class due to changes in soil moisture and vegetation canopy differences.[3] A method is needed that can classify land surfaces by their functional characteristics which are important in the linkages between the atmosphere and land surfaces. An example is the surface energy budget which can be quantified over space and time. One such classifier has been developed by Luvall and Holbo[3] and is called the thermal response number (TRN).

A change in surface temperature can be used as an aggregate expression of both surface properties (canopy structure and biomass, age, and physiological condition) and environmental energy fluxes. A change in surface temperature will be measured by the GOES–8 over a 30- to 60-min time period during cloud-free conditions. Usually a separation of about 30 min results in a measurable change in surface temperature caused by the change in incoming solar radiation. Surface net radiation is used as the value that integrates the effects of the non-radiative fluxes and the rate of change in surface temperature as the value that reveals how those nonradiative fluxes are reacting to radiant energy inputs. Their ratio can be used to define a surface property defined by Luvall and Holbo[3] as a TRN.

The thermal response number is readily calculable as a diagnostic from MM5/ RAMS model output and will be compared to the observed values generated from GOES. Analysis of the TRN spatial patterns and temporal evolution during periods that are dominated by nonprecipitating convective clouds will show how the draw down of soil moisture by surface evapotranspiration is handled by the numerical model and the effect of landcover on surface evapotranspiration.

The first year's efforts have been focused on obtaining the tools and data needed for the project.

- Land use/land cover maps have been obtained for the TVA region and have been added as a GIS layer as the structural classification of surface types.
- USGS (U.S. Geological Survey) digital elevation models (DEM) at 1:250,000 scale have been obtained for the TVA region. Integration into the GIS has begun.
- Switched from RAMS to PSU/NCAR Penn State University/National Center for Atmospheric Research) MM5 for mesoscale modeling. MM5 source code has been obtained and is compiled and running on MSFC's Crays.
- MM5 source code has been modified to assimilate GOES–8 data and is now being tested.

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[4]Pielke, R.A.; Cotton, W.R.; Walko, R.L.; Tremback, C.J.; Nicholls, M.E.; Moran, M.D.; Wesley, D.A.; Lee, T.J.; Copeland, J.H.: "A Comprehensive Meteorolgical Modeling System—RAMS." *Meteorological Atmospheric Physics*, vol. 49, pp. 69–91, 1992.

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Biographical Sketch: Dr. Jeffrey Luvall has been with NASA since 1985 and is currently at NASA's Global Hydrology and Climate Center. He has worked extensively with surface energy budget modeling using remotely sensed data. He is using the thermal response number (TRN) to quantify surface energy flux characteristics from urban areas. The use of the TRN allows the functional classification of land surfaces in modeling surface/atmospheric interaction and feedback mechanisms for use in global climate models using remotely sensed data from aircraft and satellite platforms. He has developed a portable ground-based atmospheric monitoring system (PGAMS) in conjunction with Dr. Steve Schiller, South Dakota State University, for the correction of atmospheric radiance effects on remotely sensed data. The PGAMS is currently being used in developing atmospheric radiance corrections algorithms for the future Landsat-7 data.